DOCUMENT RESUME

ED 160 385 SE 024 901

TITLE	Metrics, The Measure of Your Future: MetriCompass for Young Adults.
INSTITUTION	North Carolina State Dept. of Public Instruction, Raleigh. Div. of Development.; Winston-Salem City Schools, N.C.
SPONS AGENCY	Bureau of Elementary and Secondary Education (DHEW/OE), Washington, D.C.
PUB DATE	78
GRANT	ESEA-58-78-012
NOTE	29p.; For related documents, see SE 024 900-907; Contains occasional light and broken type
AVAILABLE FROM	Instructional Materials Development Center, 2720 South Main Street, Winston-Salem, North Carolina 27107 ($0.50)
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	*Elementary School Mathematics; Elementary Secondary Education; *Instructional Materials; Measurement; *Metric System; *Resource Materials; Secondary School Mathematics; *Supplementary Reading Materials

ABSTRACT

This booklet brings together in one place some of the new words, symbols, and concepts of SI, the modern international system of metric measurement, now being used in many different subject areas. This booklet is intended to supplement, not substitute for, metric textbooks. It can be used for quick reference as young people prepare to live and work in a society that is becoming more and more involved with the use of metric measurements. (Author/MP)

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ED160385

METRICS THE MEASURE OF YOUR FUTURE

Published by *METRIC EDUCATION - ESEA TITLE III*
A Project of the *WINSTON-SALEM/FORSYTH COUNTY SCHOOLS*
POST OFFICE BOX 2513 - WINSTON-SALEM, N.C. 27102
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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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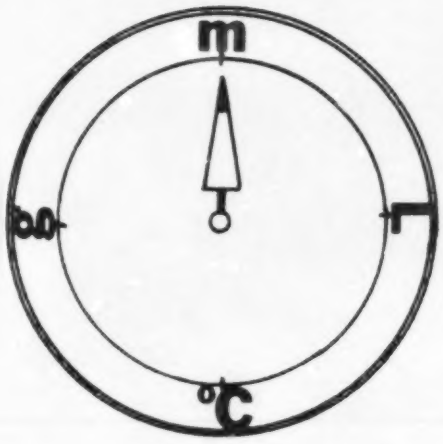
MetriCompass



for Young Adults

For use in the Winston-Salem/Forsyth County School System

Dr. James A. Adams, Superintendent
C. Douglas Carter, Special Assistant for Instruction

ESEA Title IV-C - Grant No. 58-78-012
Division of Development, North Carolina Department of Public Instruction

SE 024 901

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Materials in this volume were developed in a Metric Education Project funded by ESEA Title IV-C through the North Carolina State Department of Public Instruction, Division of Development.

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Instructional Materials Development Center
2720 South Main Street
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Spring 1978

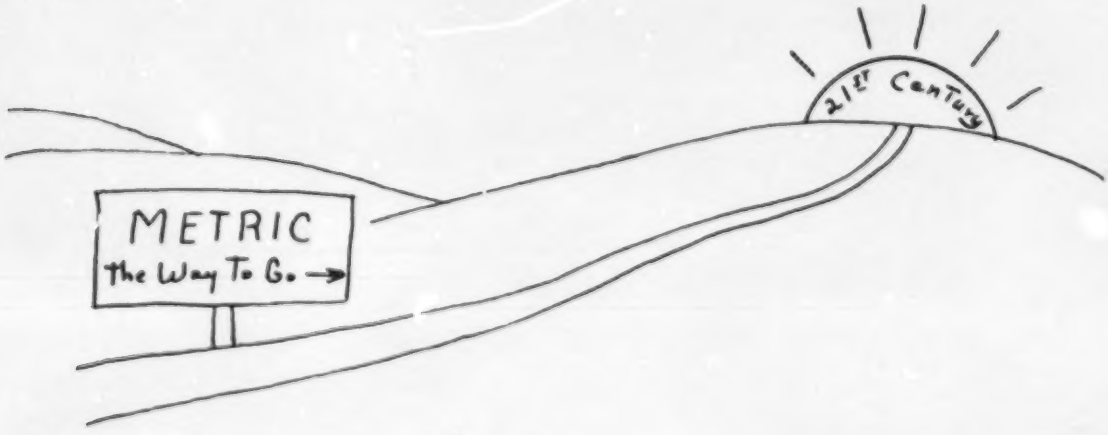
To the Young Adult:

This brings together in one place some of the new words, symbols, and concepts of SI, the modern international system of metric measurement, now being used in many different subject areas. This booklet is intended to supplement, not substitute for, metric textbooks. Use it for quick reference as you prepare to live and work in a society that is becoming more and more involved with the use of metric measurements.

Young Adults will want to develop these basic metric skills:

1. To know the commonly used words, prefixes, and symbols of the metric system and its special rules of form and style.
2. To apply the various relationships within the metric system.
3. To estimate, measure, and compare length, area, volume, capacity, mass, and temperature, using appropriate instruments with metric units.
4. To use metric measurements in basic mathematical and scientific operations.
5. To solve problems of daily activities that involve metric measurement.
6. To be aware of the background and advantages of world-wide adoption of the metric system.
7. To make general comparisons between the metric system and the customary system, using tables and formulas, particularly when confronted with the necessity of interpreting mixed data.

Achieving these goals is not an instantaneous procedure. You will reach them gradually over a period of time as you think and use metric measurement. Begin today to choose metric - it really is the measure of YOUR FUTURE!



Give me one good reason why I should change!

This challenge comes frequently to those who are trying to help this country go metric. It is almost always made by competent, successful adults, usually well-educated and quite satisfied with life as it already is. They may long ago have had a little trouble with the complicated arithmetic of our customary measurements, but no longer. The coming of the metric system offers no real threat to them, but it is no special source of joy, either. What is in it for them? Or for us?

To answer that, we must focus on "life as it already is," with America one of the great industrial nations having a standard of living, even in a depression, higher than the people of many other countries can even imagine. And we reached that happy condition without any help from the metric system--or did we?

Think back. George Washington and the Continental Congress managed to establish for us a decimal system of money that works on place value, just like metric measurements do. It gave Americans a great advantage in developing trade. President Washington also advocated use of decimal measurement before even the French adopted the metric system; the argument that defeated it then was that it had never been tried! Finally, in 1866, the metric system was made legal but optional in this country. A large part of the technology that has made our country great was developed by scientists and engineers who did choose to use metrics. The rest of us have profited from their wisdom, even while we denounced their choice!

But that old pattern cannot continue. Now more than 95% of the people of the world have chosen the metric system, and not because they love France, or like to study, or dislike inches. They have changed because the metric system really is easier to learn and to use, and because a common measurement language facilitates communication between peoples and standardization of manufactured parts. It is now expected in international trade.

Which brings us back to "life as it already is." One out of every six employed persons in this country works on export goods or their components. In exchange for those goods, we get some items (like color TVs) at lower cost and some (like oil) that we need at any price. But American manufacturers cannot afford the luxury of a dual system, making metric goods for export and customary for home folks comfortable in their old ways. To do that would require two assembly lines, separate sets of tools, double inventories, extra record keeping, and inevitably higher prices. The export goods would then be harder to sell, and ultimately our standard of living would decline. Economic necessity requires that industry go metric.

With a dual system, everyone would have to learn and use competently two separate systems, because everyone uses manufactured goods. The conclusion is inescapable: the United States must change, however comfortable our use of customary units may have been. They are an interesting relic of our past, not a viable tool for our future--especially if we cherish "life as it already is!" To preserve that, we need the metric system.

How to Learn to Love the Meter

Given that METRIC really is the measure of YOUR future, how can you come to know and love this new system? Easily! Simplicity is the clue to its success in winning over so many millions of peoples of different nationalities, races, languages, cultures and traditions. That same simplicity will make it easy for you.

Start with the meter. The word literally means the measure; it is the base unit around which the rest of the system was constructed. The meter is a length measurement about ten percent longer than our customary yard. A 100-yard football field is about 91 meters long; notice that it takes fewer meters than yards to measure the distance, since the meter is a larger unit. The meter will be used just as we have always used the yard.

In the metric system, larger or smaller units can be formed by using special prefixes before the unit name. For example, milli means thousandth; it is used with meter to make millimeter which is a thousandth of a meter. Other prefixes you will need to learn include centi, hundredth; deci, tenth; deka, ten; hecto, hundred; and kilo, thousand. You can see immediately that a kilometer is a thousand meters long, and a centimeter is a hundredth of a meter. This results in a very uniform table of length values, just like we already use for money values:

10 millimeters	= 1 centimeter	10 mills	= 1 cent
10 centimeters	= 1 decimeter	10 cents	= 1 dime
10 decimeters	= 1 meter	10 dimes	= 1 dollar
10 meters	= 1 dekameter	10 dollars	= 1 ten
10 dekameters	= 1 hectometer	10 tens	= 1 hundred
10 hectometers	= 1 kilometer	10 hundreds	= 1 thousand

Best of all, the metric system is consistent. The prefixes always have the same meaning. Used with liter, they measure liquid capacity; with gram, mass or weight. Kilo always means 1000, so a kilometer is 1000 meters, a kiloliter is 1000 liters, a kilogram is 1000 grams, and a kilowatt is 1000 watts. E - - - Z! Compare that with a table of the varied units we have been using for length:

3	barleycorns	= 1 inch
12	inches	= 1 foot
3	feet	= 1 yard
9	inches	= 1 span
5	spans	= 1 ell
5	feet	= 1 pace
125	paces	= 1 furlong
5½	yards	= 1 rod
40	rods	= 1 furlong
8	furlongs	= 1 statute mile
1760	yards	= 1 mile
5280	feet	= 1 mile
12	furlongs	= 1 league

Say it in METRIC - a new language of measurement.

The general rule for pronunciation of metric words is to accent the first syllable. Very often the word will be written as a symbol following a number. These symbols are not abbreviations, so they are followed by a period only at the end of a sentence. Some are capitalized, some are not.

This word	or symbol	sounds like:	Read aloud:
gram	g	gram	A raisin weighs about a gram.
meter	m	meet er	A meter is a little more than a yard.
liter	L	leet er	A liter is a little more than a quart.
Celsius	C	sell see us	Celsius invented the centigrade scale.
kelvin	K	kell vin	One kelvin equals one degree Celsius.
ampere	A	am pier	Amperes measure electric current.
second	s	sec ond	Seconds measure time intervals.
mole	mol	mole	Moles measure molecular weight.
But:			
candela	cd	can dell ah	The candela measures luminous intensity.

Metric prefixes also should be accented on the first syllable and mean the same thing when used before any metric word:

exa	E	ex ah	quintillion	An exameter	= 1 000 000 000 000 000 000 m
peta	P	pet ah	quadrillion	A petameter	= 1 000 000 000 000 000 m
tera	T	terr ah	trillion	A terameter	= 1 000 000 000 000 m
giga	G	jig ah	billion	A gigameter	= 1 000 000 000 m
mega	M	meg ah	million	A megameter	= 1 000 000 m
*kilo	k	kill oh	thousand	A kilometer	= 1 000 m
hecto	h	heck toe	hundred	A hectometer	= 100 m
deka	da	deck ah	ten	A dekameter	= 10 m
deci	d	dess y	tenth	A decimeter	= 0.1 m
*centi	c	cent y	hundredth	A centimeter	= 0.01 m
*milli	m	mill y	thousandth	A millimeter	= 0.001 m
micro	μ	mike row	millionth	A micrometer	= 0.000 001 m
nano	n	nan oh	billionth	A nanometer	= 0.000 000 001 m
pico	p	peek oh	trillionth	A picometer	= 0.000 000 000 001 m
femto	f	fem toe	quadrillionth	A femtometer	= 0.000 000 000 000 001 m
atto	a	at oh	quintillionth	An attometer	= 0.000 000 000 000 000 001 m

*Most daily activities will involve only these. Take a closer look at them:

10 millimeters = 1 centimeter
100 centimeters = 1 meter
1000 meters = 1 kilometer

Compare that easy relationship with one you already know:

12 inches = 1 foot
3 feet = 1 yard
1760 yards = 1 mile
or 5280 feet = 1 mile

. . . 5270, 5271, 5272, 5273, 5274, 5275, 5276, 5277, . . .

Most-used metric units - what do they measure?

Length

millimeter (mm) 1000 mm = 1 m	for precision measurements in engineering, crafts, building, industry, etc.
centimeter (cm) 100 cm = 1 m	body measurements, clothing, household goods, most items previously measured in inches
meter (m)	in place of foot and yard measurements in general
kilometer (km) 1000 m = 1 km	highway distances, maps, etc., replacing miles

Area

square centimeter (cm^2) 1 cm x 1 cm = 1 cm^2	small items like snapshots, page layouts, graphs formerly measured in square inches
square meter (m^2) 1 m x 1 m = 1 m^2	floor and carpet sizes, replacing square feet and square yards
hectare (ha) 100 m x 100 m = 1 ha	all areas formerly measured in acres
square kilometer (km^2) 1000 m x 1000 m = 1 km^2	very large land areas, previously stated in square miles

Volume

cubic centimeter (cm^3) 1 cm x 1 cm x 1 cm = 1 cm^3	sometimes replacing cubic inches
cubic meter (m^3) 1 m x 1 m x 1 m = 1 m^3	cement, lumber, other bulky items formerly measured in cubic feet and cubic yards

Capacity

milliliter (mL) 1000 mL = 1L	beverages, liquid medicines, recipe quantities formerly given by ounce, cup, or spoon
liter (L) 1 L = 1 dm^3	gasoline, oil, milk, other liquids formerly measured in quarts and gallons

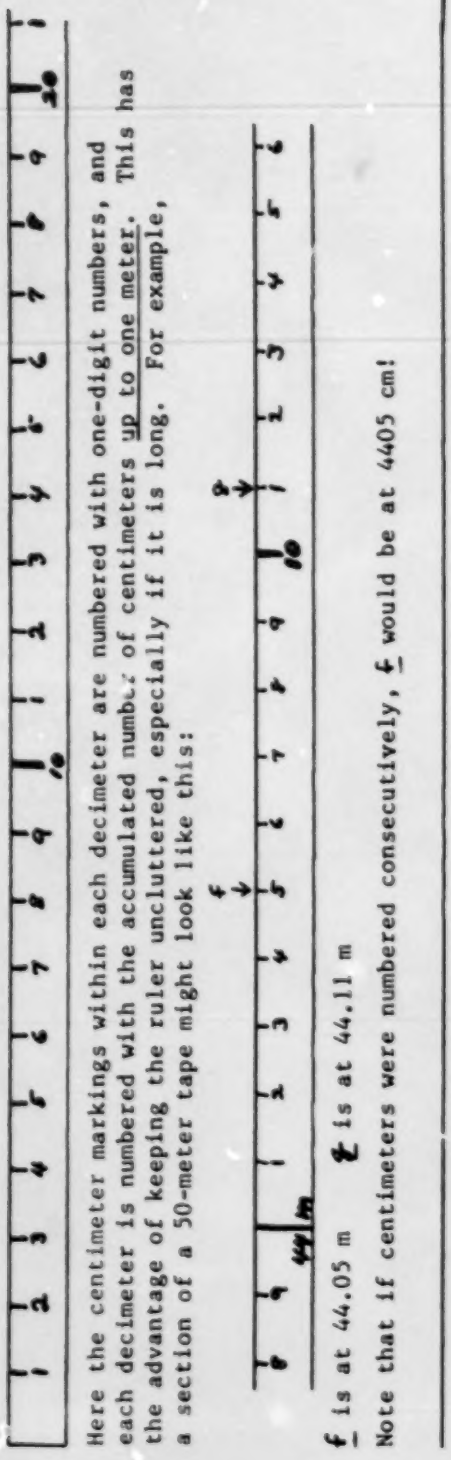
Weight or Mass

milligram (mg) 1000 mg = 1 g	medicines, vitamins, other very small quantities
gram (g)	foodstuffs less than a kilogram, formerly weighed in pounds and ounces
kilogram (kg) 1000 g = 1 kg	body weights, foodstuffs, packages up to a metric ton
metric ton (t) 1000 kg = 1 t	very large quantities, as coal, grain and ore shipments, truck loads

Temperature

degree Celsius (°C)	weather conditions, body temperature, ovens

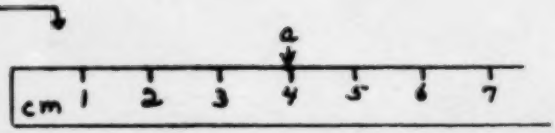
How To Read A Metric Ruler



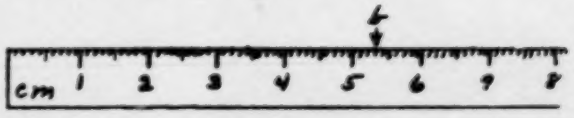
Here the centimeter markings within each decimeter are numbered with one-digit numbers, and each decimeter is numbered with the accumulated number of centimeters up to one meter. This has the advantage of keeping the ruler uncluttered, especially if it is long. For example, a section of a 50-meter tape might look like this:

f is at 44.05 m g is at 44.11 m

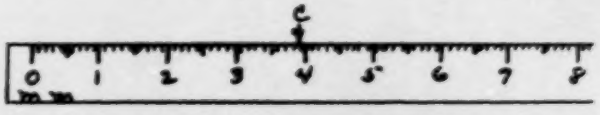
Note that if centimeters were numbered consecutively, g would be at 4405 cm!



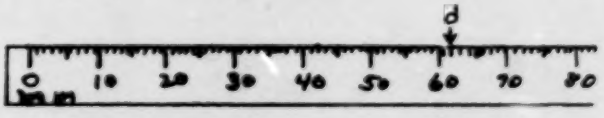
Marked in centimeters, labeled and numbered in centimeters. Good classroom ruler for young students. a is at four centimeters.



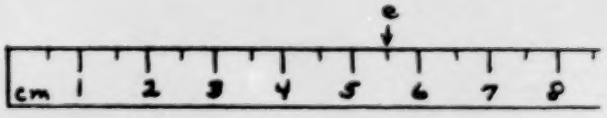
Marked in centimeters and millimeters, labeled and numbered in centimeters. Preferred by many teachers. (Note that ruler is dead length: does not extend to left of 0). f is at 5.3 centimeters.



Marked in centimeters and millimeters, numbered in centimeters, labeled in millimeters to indicate smallest unit accurately measured. Preferred by some draftsmen. c is at 3.9 centimeters or 39 millimeters.



Marked in centimeters and millimeters, labeled and numbered in millimeters. Preferred by some engineers, usually in short lengths (the numbers become large very quickly). d is at 62 millimeters.



Marked in centimeters and half-centimeters, numbered and labeled in centimeters. Preferred by some retail clothing salespersons. e is at 5.5 centimeters.

Make a Place for Metrics in Your Mind

Sometimes, after you have measured carefully with a metric ruler or tape, a question arises as to the best or most useful form for your results.

Suppose you have measured a rectangle that is 92 cm long and 70 cm wide, then compute its perimeter:

Perimeter	= 2 (length)	+	2 (width)
	= 2 (92 cm)	+	2 (70 cm)
	= 184 cm	+	140 cm
	= 324 cm		

Note that this is a correct answer, one you would expect if measuring in centimeters. But since it is a rather large number of centimeters, you might want to change it to meters. In doing that, let's first write the measurement under a metric place value chart so that it ends at centimeters, the given unit:

km	hm	dam	m	dm	cm	mm
			3	2	4	

Remember that a whole number has a decimal point understood after its units place, shown by the dot in the little circle. Now, to change from centimeter units to meter units, simply move the decimal so it follows meters, the new unit, shown by the point of the arrow. Now the measurement reads 3.24 meters. The decimal always follows the unit named.

This method of changing from one unit to another works for either larger or smaller units. A measurement like 0.14 meters may be changed to centimeters; write it under a metric place value chart with the decimal following meters, the given unit:

km	hm	dam	m	dm	cm	mm
			0	1	4	

Moving the decimal to the new unit gives a reading of 14 centimeters.

This process of changing from one unit to another is one that you will want to do "in your head" after some practice, just as you would add 75¢ and 47¢ to get 122¢, then think of that as $1.22 without any arithmetic on paper; or you would know that $3.43 might represent 343 pennies.

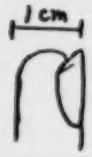
Since the metric system is consistent, this process works for all metric units, making it easy to choose the unit most suitable for your own purpose. For example, a 1000 mg tablet contains 1 gram of vitamin C:

kg	hg	dag	g	dg	cg	mg
			1	0	0	0
5	0	0	0			

A carton holding 5000 tablets contains 5000 grams or 5 kilograms of the substance. A druggist might describe his stock in kilograms, but a doctor would always prescribe a dose in milligrams.

Moving along with the meter

While you were looking over the examples of metric rulers on page 6, you were probably saying to yourself that "a ruler is a ruler," and you are exactly right. There is no difference in the way we use them, metric or customary. The only difference is in the size of the spaces marked off and the names for these spaces.



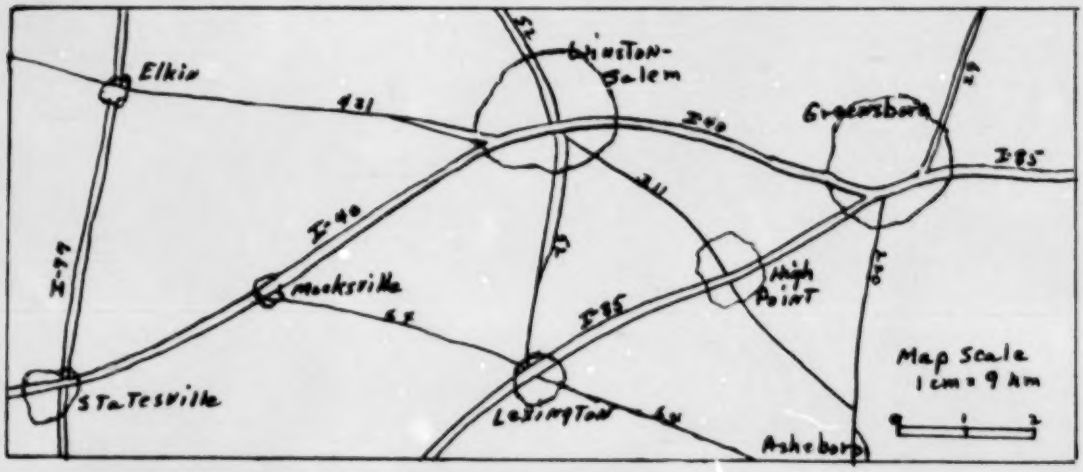
Try to find a way to remember how wide a centimeter really is - maybe one of your fingernails is that wide or the thickness of your little finger. Having such a "personal scale" will make it easy for you to estimate small widths or lengths. For even smaller items, remember that a dime is about a millimeter thick.

The width of your palm or fist may be about 10 cm or 1 decimeter. This will help with estimations of areas like table tops, chair seats, etc. And if you have always estimated a yard as the distance from your nose to your fingertips, just turn your face away a bit and you're very close to a meter!

The only time most of us will think about kilometers will be in connection with our cars and travel. Since a kilometer is only six tenths of a mile, familiar places will sound much farther away: 6 miles make 10 kilometers. And a sixty-mile drive will register 100 km on your odometer, if it is metric! Don't change your old car from miles to kilometers, though; tampering with the odometer is illegal in North Carolina.

We will have to get accustomed to new speed limit signs - our present 55 mph limit is comparable to 88 km/h (notice the correct way to write kilometers per hour.) Another thing that will take getting used to is the way to measure fuel usage - instead of claiming our car gets 30 miles per gallon, we may brag that it uses only 8 liters per 100 kilometers.

Reading a metric roadmap will be just like reading one in miles if the distances are already calculated for you. If not, using centimeters and/or millimeters in the scale will make accuracy easier than the old ones with inches and fractions.



Metric arithmetic?

In the words of Gomer Pyle, "Surprise, surprise!" There is no new mathematics for use with the metric system. Everything we will need to do has already been done with customary units. But there are some points we should keep in mind:

1. Common fractions will not be used in measurements; parts of units will be expressed with decimals. A meter and a half is always written as 1.5 meters. This is like our money usage - we may say "a dollar and a half for lunch," but we write $1.50; compare that with "a yard and a half," which is frequently written as 1½ yards.

2. One number, with or without a decimal, will express the entire measurement - no more expressions like 5 yards, 2 feet, 11 inches. Measured with a meter stick, that will be 5.461 meters.

3. When measuring a space or object, all measurements should be expressed in the same unit if further computations will be made.

4. Addition and subtraction of metric measurements in the same unit will be just a matter of lining up the decimal points and adding or subtracting, like money (be sure to write the symbol):

$4.12 + 1.43 = $6.15 $9.63 - 8.08 = $1.55

2.18 m + 3.45 m = 5.63 m 6.05 m - 4.14 m = 1.91 m

5. Metric measurements may also be multiplied or divided by a number, just like sums of money:

$2.98 × 3 = $8.94 1.356 m × 4 = 5.424 m

$2.30 ÷ 2 = $4.60 (4, 6, 6, 0, 0)

3.94 m ÷ 2 = 7.88 m (6, 18, 18, 8, 8)

6. When one measurement is multiplied times another, as when finding area and volume, the decimals require careful attention. (See example, page 10) Always remember that the number of decimal places marked off in the answer is equal to the sum of the number of places marked off in the two numbers being multiplied together. After the decimal is placed, the answer is usually rounded off to no more places than were in the numbers being multiplied. Two like units multiplied together always make a square unit; three units multiplied together make a cubic unit.

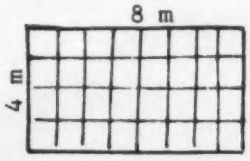
Some "plane" facts about the meter

When metric units of length seem familiar and reasonable to you, it is time to consider some other uses for the meter. Probably most common is the matter of finding the area of a flat surface. Area is length multiplied by width. But width is just a length measurement made crosswise on the space. So another true statement is: Area is a product of two length measurements.

A space one meter long by one meter wide is called one square meter:

$1 \text{ m} \times 1 \text{ m} = 1 \text{ m}^2$

When you are asked to find the area of a rectangular space, what you really need to know is how many of these square meters would fit neatly into it. For example, given a space 4 meters by 8 meters:

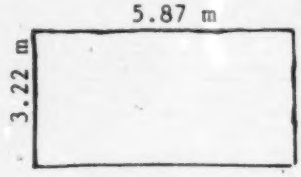


Obviously, you could mark it off into one-meter squares, then count them; or you could multiply:

$4 \text{ m} \times 8 \text{ m} = 32 \text{ m}^2$

The only problem arises when the length and/or width measurements do not come out even. Remember measurements like 5 yards, 2 feet, 7½ inches by 3 yards, 1 foot, 11 inches? Multiplying those was a task not easily accomplished! It meant changing all units to inches, multiplying, then dividing by the number of square inches in a square yard (1296, in case you forgot).

Let's look at a similar case using metric measure:



Note that both dimensions are measured in meters, accurate to the nearest centimeter, which is less than half an inch.

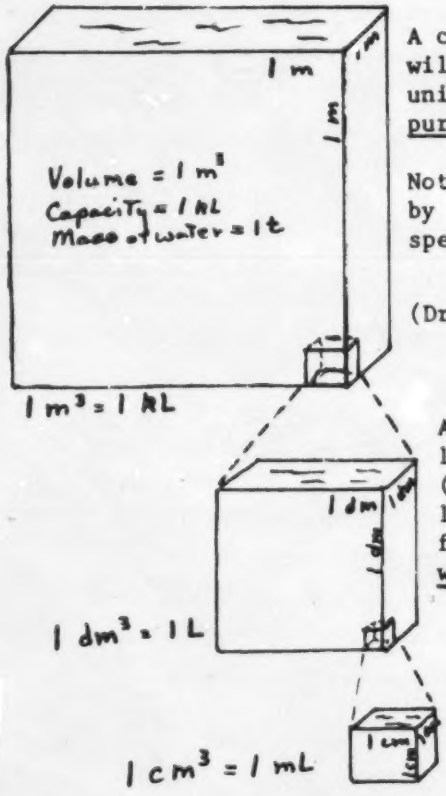
5.87 m → 2 decimal places
× 3.22 m → + 2 decimal places

1174
1174
1761

18.9014 m² ← 4 decimal places

The answer would then usually be rounded off to no more places than were used in the original measurements; the area is about 18.90 m^2.

Careful Measuring that Liquid - It's in milliliters!



A container with inside dimensions 1 m x 1 m x 1 m will hold 1 cubic meter (1 m^3). This is the base unit for volume in the metric system. This much pure cold water will weigh a metric ton!

Note that either solids or liquids may be measured by this volume unit - but read on! Liquids do have special treatment in the metric system.

(Drawings are not to scale!)

A container with inside dimensions 1 dm x 1 dm x 1 dm will hold 1 cubic decimeter (1 dm^3). Another name for this quantity is 1 liter; metric prefixes are used with liter for larger or smaller units. A liter of water weighs 1 kilogram. (1000 L = 1 kL = 1 m^3)

A container with inside dimensions 1 cm x 1 cm x 1 cm will hold 1 cubic centimenter (1 cm^3). This is the same quantity as one milliliter, and this much water weighs one gram. (1000 mL = 1 L)

Generally speaking, the cubic meter, cubic decimeter and cubic centimeter are used for measurements of solids or of spaces, while the liter, the milliliter, and (sometimes) the kiloliter are used for liquids and things that pour.

Buying liquids in metric measures will not pose any special problems. The liter is only 6% larger than a quart, and should cost about that much more. Suppose you have been paying 64¢ a gallon for gasoline (16¢ a quart); the new price should be about 17¢ a liter. Anything higher would represent a real price (or tax) increase. Some other nations have made it illegal to raise the price of an item when changing from one system to another; the United States does not have that restraint on trade. Our best protection as consumers is to buy from known and trusted dealers when buying gasoline, milk, fuel oil, or any other goods.

One big advantage in metrics is that canned goods won't be marked in ounces, leaving us forever to wonder if that refers to the capacity of the container or to the weight of the contents! Capacity will be liters or milliliters; weight will be grams or kilograms - it's as easy as that!

The milliliter is a small quantity (a teaspoon holds 5 mL) that will make accurate liquid measurement easy; it is the same unit that used to sound so mysterious when doctors and nurses talked about injecting three c.c.'s of antitoxin, using the old abbreviation for cubic centimeter.

Need a Mass of Information about Metric Weight?

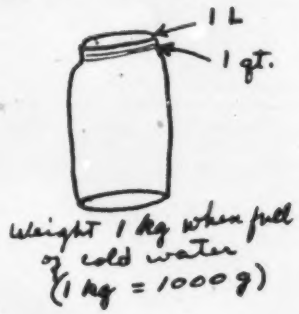
One of the first things most adults really enjoy about the metric system is finding out their own weight in kilograms. One kilogram is a little more than two pounds; it is the most-used unit of weight. Since kilograms are large units, the scale indicator stops on a much smaller number. Here is truly a time to forget about conversions and just enjoy what you read! Only a spoil-sport or a fullback would want to double it and add ten percent, thus changing back to pounds!

The larger unit does suggest that you use caution in ordering that Thanksgiving turkey - a 20-kilogram bird would weigh 44 pounds and make enough leftovers to last until Easter. Be prepared, too, to pay more than twice as much per kilogram as the old price per pound (see page 13).

Many cooks worry needlessly about continental recipes that list ingredients by weight. These are easy to use with a gram scale you can buy in most housewares departments. But American recipes will continue to be given in volume measurements just as they always have been. A "standard" metric cup will hold 250 milliliters (just two teaspoons more than the old half-pint one). Metric measuring cups are readily available and easy to use accurately.

Another source of adult concern is the frequent use of the word mass instead of weight. Mass is the quantity of matter in a given object, without the effect on it of gravity or any other force. Since pounds were used to measure both mass and force, and weight was used with both, much confusion resulted. Now with metric units, mass (or weight) will always be measured in kilograms and force in newtons, a derived unit. Just another instance of metrics solving a measurement problem simply and easily.

If the comparisons between metric units seem strange to you, try relating them to some common objects. A nickel weighs five grams, and so does a teaspoon of cold water, which is five milliliters. A wide-mouthed quart mayonnaise jar holds one liter filled to the top - and that much water weighs a kilogram. Or lift some butter; 9 sticks is a little over a kilogram. Trials like this help you to develop the ability to estimate metric weights, a skill that depends on cooperation between your brain and your muscles.



Large quantities will not seem to change so much. One thousand kilograms make one metric ton, which is about 2205 pounds, a tenth more than the customary "short ton."

The Metric Shopper

If you try to be a careful shopper, metric container sizes and weights will make comparisons much easier. The rule for finding cost per pound has always been in two steps:

1. Express the weight of the item in pounds, then
2. Divide the weight in pounds into the cost.

That was easy enough to do when the weight was a whole number of pounds; but when it was something like 2 pounds 6½ ounces, the first part became so difficult that the average shopper gave up and made an "educated guess."

With metric measures, the rule is almost the same as before:

1. Express the weight of the item in kilograms, then
2. Divide the weight in kilograms into the cost.

However, with metric measures the first step is not such a stumbling block. Amounts larger than one kilogram will be expressed as a single number already, using decimal fractions for any parts of units. An amount less than one kilogram may also already be in kilograms, as 0.142 kg. But if it is not, as in 327 grams, it can be changed to kilograms simply by moving the decimal three places left, to read 0.327 kg (see example, page 7).

Dividing by a three-decimal place number may not strike you as especially easy. Consider the case of an item marked 1.361 kg for $4.59:

$3.37 = cost per kilogram

1.361) $4.590 00

4 083

5070

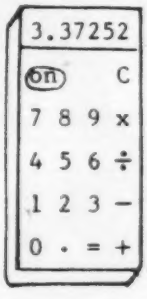
4083

9870

9527

Remember, when dividing by a number containing a decimal, (1) move the decimal to the right end of that number, (2) move the decimal the same number of places to the right in the cost (use zeros to fill enough places to include cents), (3) place a decimal in the answer directly above the one in the cost.

Of course, the easy way is to use a pocket-sized calculator right in the store!



Enter cost in dollars ⟶ 4.59

Push ÷

Enter weight in kilograms ⟶ 1.361

Push =

Read cost per kilogram ⟶ $3.37
(round off to cents)

Let's be precise, now

Whenever precision of measurement is really important, the advantage of using metric units quickly becomes obvious. Since there are 25.4 millimeters in one inch, it is possible to use any good metric ruler and measure accurately to the nearest millimeter, or to the nearest twenty-fifth of an inch! The usual customary ruler is marked to sixteenths of an inch. Even more important than the easy visual accuracy, however, is the fact that so many measurements may be made using millimeters as units, with never a common fraction. Many industries that require careful fitting of parts make all their measurements in millimeters, using metric micrometers to measure tenths and hundredths of millimeters. (When micrometer is pronounced with the accent on the second syllable, my crom eter, it refers to a measuring tool; when the accent is on the first syllable, mike row meter, it is a length unit one thousandth of a millimeter long.)

Similar precision with weights is possible, using the gram unit, which is one twenty-eighth of an ounce; and liquids may be be measured by the milliliter, which is about one thirtieth of an ounce. Special scales and graduated containers are needed for any greater degree of accuracy, just as the micrometer is needed for measurements smaller that a millimeter.

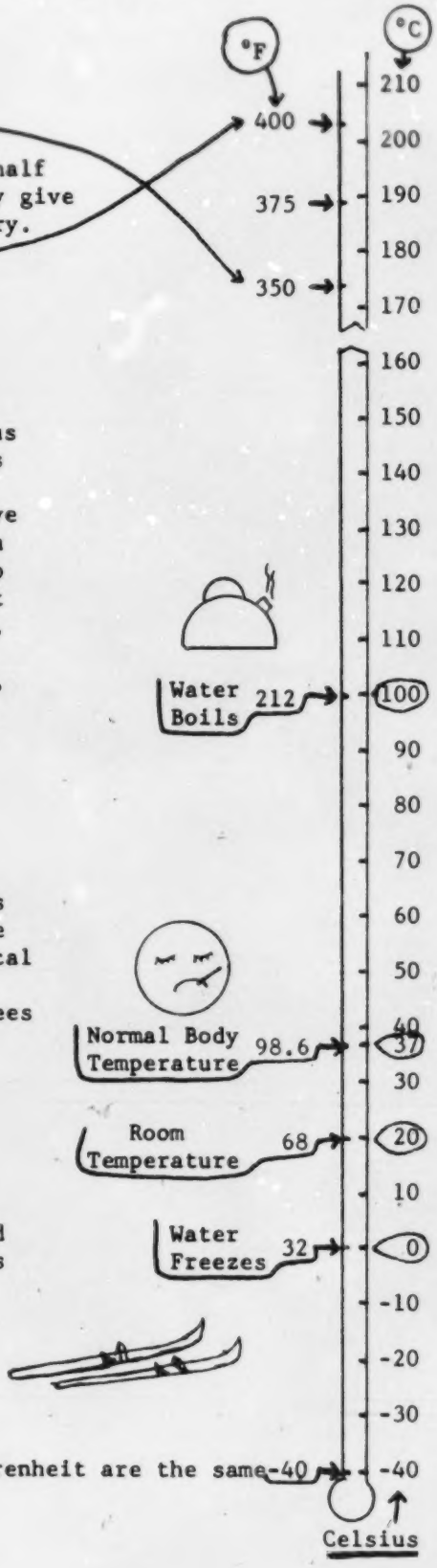
Here is a table showing some of the most-used fractional parts of the inch, ounce, and fluid ounce:

Inch →	millimeters	Ounce → grams	Fluid ounce → milliliters
1/2	12.7	14.175	14.8
1/4	6.35	7.087	7.4
3/4	19.05	21.261	22.2
1/8	3.175	3.544	3.7
3/8	9.525	10.631	11.1
5/8	15.875	17.718	18.5
7/8	22.225	24.806	25.9
1/16	1.5875	1.772	1.8
3/16	4.7625	5.316	5.5
5/16	7.9375	8.859	9.2
7/16	11.1125	12.403	12.9
9/16	14.2875	15.947	16.6
11/16	17.4625	19.490	20.3
13/16	20.6375	23.034	24.0
15/16	23.8125	26.578	27.7

The column of millimeter measurements are exact equivalents of the fractional parts of an inch; the other two columns are approximations. For most daily use, all can be rounded off with no decimal parts. To do that, look only at the digit following the decimal in the number you want to use: if that digit is less than 5, simply discard the entire decimal part of the number; if that digit is 5 or more, discard the decimal part, then add 1 unit to the remaining whole number.

Keep your Cool about degrees Celsius!

Oven Temperatures for Baking:
Using a Celsius temperature that is about half the customary Fahrenheit one will generally give satisfactory results. Individual ovens vary.



For easy peace of mind, learn the four Celsius temperatures circled at right. Water freezes at 0°C and boils at 100°C. Keeping your thermostat at or below 20°C will help conserve fuel, though you may want long sleeves if you are inactive. When outside temperatures drop to 10°C you will add a sweater or jacket. At 0°C you will want a warm coat, adding gloves, scarf, etc., as it goes lower. On the other hand, as temperatures rise from 20°C to 30°C, outdoor activities such as picnicking and swimming become popular. Above that you'll just look for shade trees!

Normal human body temperature is 37°C. One hard thing to remember is that 38°C is "running a temperature" and 39°C is a serious fever requiring special attention (it is more than 102°F). And 40°C is a signal for critical concern. Don't forget that a rise of one degree Celsius is almost as much as two degrees Fahrenheit.

If the Celsius thermometer looks rather familiar to you already, it is probably because you used it before in a laboratory and called it centigrade. It has been renamed Celsius to honor the man who invented it (we always honored Fahrenheit by using his name for our everyday thermometers).

This is the only point where Celsius and Fahrenheit are the same.

Writing about metric measures

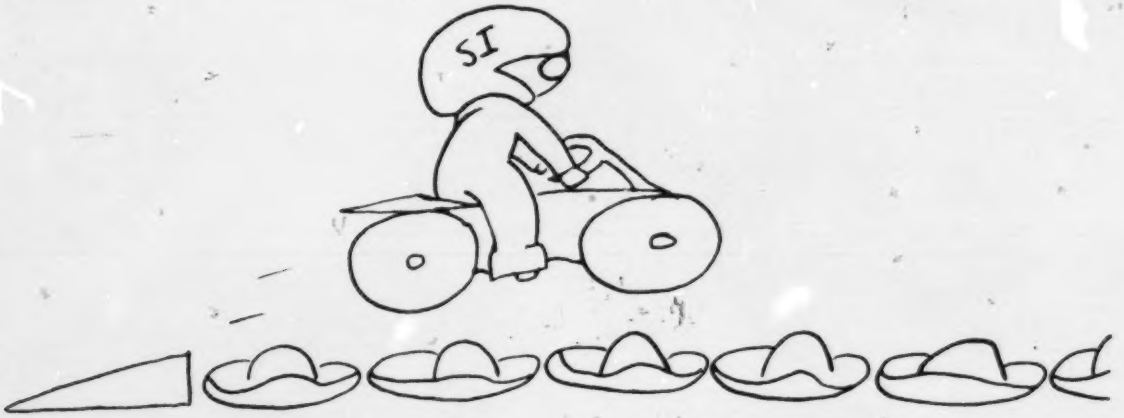
In writing material incorporating measurements, begin now to use metric units. If it seems desirable to add customary equivalents, put the amount in parentheses following the metric quantity. This way your material will have a longer life expectancy! If you must pass along data given to you in customary units, follow each item with its metric equivalent; indicate the source of the data to show it was not your choice.

In technical publications, the equivalent term should be stated to the same degree of accuracy required in the use of such data. In other writings, the equivalent value should be rounded off to appropriate units or stated as a comparison:

- The average driver purchases 50 liters (quarts) of gasoline each week.
- Dr. Seldon advised dieters to include four ounces (115 grams) of protein in each day's food allowance.
- The speed limit may soon be 88 km/h (55 mph).
- Recommended thickness of the steel plate is 4.36 mm (0.172 in.)

In general writings, the comparisons may be dropped after a repetition or two. In technical materials, such as a machine design, a dress pattern, or a floor plan, they should be continued throughout as an aid to users not well familiar with metric units.

Don't try to convert old sayings or familiar expressions - make up a new one in metric terms. Leave the ten-gallon hat to its place in western legend; let today's hero wear a 50-liter crash helmet!



Spelling is a problem only when material will be used both here and abroad. Preferred spellings established by the Secretary of Commerce under Public Law 94-168 include meter, liter, gram, deka, and ton. Many other English-speaking nations use metre, litre, and deca, and often use tonne to avoid always having to precede it by metric. The old gramme spelling is obsolete and being phased out.

Materials to be published in this country should certainly follow the U. S. guidelines; correspondence may, of course, use the form most familiar to the writer or to the addressee. Spelling should be consistent throughout.

How to Write it Right

1. Unit names, prefixes and symbols must follow SI rules exactly.

2. When written out, unit names are capitalized only when they are at the beginning of a sentence, except for Celsius which is always capitalized.

3. Do not space between a numerical prefix and the unit name; never use a numerical prefix without a unit name: 17 kilograms not kilo grams or kilos.

4. When the unit name is spelled out, use "s" for the plural: 114 meters

5. Symbols are the same for singular or plural; never add "s" to a symbol.

6. Unit symbols are always written exactly as they appear in the SI tables; the meaning may vary with capitalization: m means milli, M means mega

7. Symbols are followed by periods only at the end of a sentence; they are not abbreviations.

8. When a symbol contains several letters, leave no spaces between them.

9. Leave a space between the number and the symbol: 73 m (except 17°C)

10. Use a period as a decimal marker (some countries use a comma): 3.5 m

11. When the number is less than one, always use a zero before the decimal point: 0.052 mg

12. Use a space instead of a comma to divide a long number into groups of three digits, beginning at the decimal and moving either right or left: 142 985 kg and 78.937 47 km

13. When the number has four digits either to the right or left, write them without spacing except when they are in a column with numbers of more than four digits: 1230 m or 0.7009 g

14. When a compound unit is formed by multiplication, use a raised period between the letters: N·m for newton-meter. Do not use the raised period between words; use a hyphen or a space.

15. When a compound unit is formed by division, use an oblique slash between the letters: km/h for kilometers per hour. Do not use the slash between words; write out per. Do not mix symbols and words: km/hour is wrong. When in doubt, spell it out.

16. Most typewriters are not equipped with the superior 2 and 3 or with the symbols for micro and ohm. The names of units like square meter and cubic centimeter may be spelled out, or the symbols may be typed with the regular 2 and 3 a half-space above the line: m^2 and m^3. The symbol for micro may be typed as u, then a tail added on the left by hand: μ The symbol for ohm may be drawn in by hand Ω or the word may be spelled out.

BASE AND DERIVED UNITS

The metric system has seven base units that measure independent quantities and two supplementary units for plane and solid angles. The base units are meter, kilogram, second, ampere, kelvin, mole, and candela. Note that one of these, the kilogram, already has a prefix; other prefixes are used with the root word gram when measuring the mass or weight of an object, but the gram is such a small quantity that the kilogram is considered the base unit. The second is a familiar time unit, and the ampere has been in general use since electric current became a common power source. The kelvin temperature scale begins at absolute zero and is used in laboratories; each unit is equal to one degree Celsius, which has zero at the freezing point of water. The mole and the candela and the two angle measures, radian (rad) and steradian (sr), have highly specialized uses.

Units for all other quantities are derived from these nine units. The metric system is coherent: each derived unit can be expressed as a product or ratio of the base units without numerical factors other than one. Seventeen derived units have special names:

Quantity	Unit Name	Symbol	Means	Sounds Like
frequency	hertz	Hz	s^{-1}	hurts
force	newton	N	$m \cdot kg/s^2$	newt n
pressure, stress	pascal	PA	N/m^2	ras cal
energy, work, quantity of heat	joule	J	$N \cdot m$	tool
power, radiant flux	watt	W	J/s	hot
quantity of electricity, electric charge	coulomb	C	$A \cdot s$	coo lomb
electric potential, potential difference electromotive force	volt	V	W/A	bolt
capacitance	farad	F	C/V	fair ad
electric resistance	ohm	Ω	V/A	home
conductance	siemens	S	A/V	sea mons
magnetic flux	weber	Wb	$V \cdot s$	wee ber
magnetic flux density	tesla	T	Wb/m^2	tess la
inductance	henry	H	Wb/A	hen ry
luminous flux	lumen	lm	cd/sr	loo men
illuminance	lux	lx	lm/m^2	lucks
activity (radioactive)	becquerel	Bq	s^{-1}	bek rell
absorbed dose	gray	Gy	J/kg	tray

Remember that Celsius is the only word used as a unit name that is capitalized, but many of the symbols include a capital letter. Great care must be exercised, for the same letter may have two meanings:

mm millimeter	T tesla	s second
Mm megameter	t metric ton	S siemens

All other derived units are similarly coherent. Only a few are in general use:

area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2

AN OUTLINE OF HISTORY - METRIC, THAT IS

1670 Gabriel Mouton, Vicar of St. Pauls Church in Lyons, proposed a decimal system based on an arc of a great circle of the earth.

1786 Decimal system of coinage, developed by Thomas Jefferson and Robert Morris, adopted by Congress - base unit the dollar.

1790 Decimal system of weights and measures proposed by Jefferson but rejected.

1795 Metric system developed by the French Academy of Science made mandatory in France (and imposed on Holland and Belgium in defeat).

1798 First International Conference on Weights and Measures called by Talleyrand.

1821 John Quincy Adams recommended that the United States not change until both England and Spain agreed. They did not.

1850 Spain, Greece, Norway and part of Italy adopted the metric system.

1866 Act of Congress made metric system legal but not mandatory in the U.S.

1868 Germany and Portugal adopted the metric system.

1875 U.S. signed "Treaty of the Meter" with 17 countries.

1893 All United States measurements redefined in terms of the meter.

1960 SI Metric System adopted by Eleventh General Conference - this modernized version amounts to an international language of weights and measures.

1965 England goes metric and changes to a decimal money system.

1968 Congress orders a study of the probable effects of making the metric system mandatory and asks for recommendations.

1970 Canada adopts a conversion plan.

1971 Study Commission reports that the United States is gradually going metric on a voluntary basis; that the change will be easiest and least expensive if carried out over a carefully planned ten-year period; and that educational efforts must be increased to meet work force needs.

1974 Congress passes Public Law 93-380 "...to encourage educational agencies and institutions to prepare students to use the metric system..."

1975 Congress passes Public Law 94-168 to set up a Metric Conversion Board to plan U.S. conversion. We have joined the metric world!

Bringing measurement up to date

One complication to the process of changing from customary to metric units is the fact that the law says we all will change, but not that everyone must change by a certain time. Some industries and businesses have moved very rapidly; others are still thinking it over. So, many people will have to be able to work in either system over the next few years.

Another problem is the fact that we simply cannot throw away all the information we have based on old units, even when metrics is required every day. Some people will have to be able to take old measurements and bring them up to date. To do that is very easy - it involves use of a number called a conversion factor. Look at this table of common measures:

Customary Unit → X →	Conversion Factor → = →	Metric Unit
inches	2.54	centimeters
feet	0.304 8	meters
yards	0.914 4	meters
miles	1.609 344	kilometers
quarts	0.946 353	liters
fluid ounces	29.573 43	milliliters
pounds	0.453 592	kilograms
ounces	28.349 523	grams
Customary Unit ← x ←	Conversion Factor ← ÷ ←	Metric Unit

To change from an old unit to a metric unit, multiply by the conversion factor. For example, if your old pattern calls for 35 ounces of yarn to make a sweater, and the yarn is labeled in grams, you would do this:

Write the number of ounces → 35

Multiply by the conversion factor → X 28.3

(Round off to one decimal; knitting is not exact) 105 280 70

Number of grams required → 990.5

(Better buy a little extra, say 1000 grams) Buy 1000 grams!

If the opposite case is true and you must change metric to customary, divide the metric quantity by the conversion factor: conv. factor) metric unit / customary unit

When your job requires this kind of conversions, you will want to have a book containing very accurate conversion factors, and you will do your arithmetic with a calculator. Or you will use a calculator or computer already programmed to do these operations.

Direct Conversions from Customary to Metric

Length

Inches	Centimeters
1	2.54
2	5.08
3	7.62
4	10.16
5	12.70
6	15.24
7	17.78
8	20.32
9	22.86
10	25.40
11	27.94
12	30.48

Feet	Centimeters
1	30.48
2	60.96
3	91.44

Yards	Meters
1	0.91
2	1.83
3	2.74
4	3.65
5	4.57
6	5.49
7	6.40
8	7.32
9	8.23
10	9.14
100	91.44
1000	914.40

Liquids

Fluid Ounces	Milliliters
1	30
2	59
3	89
4	118
5	148
6	177
7	207
8	237
9	266
10	296
11	325
12	355
13	384
14	414
15	444
16	473
17	503
18	532
19	562
20	591
21	621
22	651
23	680
24	710
25	739
26	769
27	798
28	828
29	858
30	887
31	917
32	946

Quarts	Liters
1	0.946
2	1.893
3	2.839
4	3.785

Gallons	Liters
1	3.8
2	7.6
3	11.4
4	15.1
5	18.9
6	22.7
7	26.5
8	30.3
9	34.1
10	37.9
25	94.6
50	189.3
100	378.5
1000	3785.4

Weight

Ounces	Grams
1	28
2	57
3	85
4	113
5	142
6	170
7	198
8	227
9	255
10	283
11	312
12	340
13	369
14	397
15	425
16	454

Pounds	Kilograms
1	0.454
2	0.907
3	1.361
4	1.814
5	2.268
6	2.722
7	3.175
8	3.629
9	4.082
10	4.535
25	11.572
50	22.680
100	45.359
1000	453.592
2000	907.185
2205	1000.

Temperature

°F	°C
482	250
464	240
446	230
428	220
410	210
392	200
374	190
356	180
338	170
320	160
302	150
284	140
266	130
248	120
230	110
212	100*
194	90
176	80
158	70
140	60
131	55
122	50
113	45
104	40*
95	35
86	30
77	25
68	20*
59	15
50	10
41	5
32	0*
23	-5
14	-10
5	-15
-4	-20
-13	-25
-22	-30
-31	-35
-40	-40*

RELATIONSHIPS WITHIN THE METRIC SYSTEM

1	kilometer	=	10	hectometers	=	100	dekameters	= 1 000 meters
0.1	kilometer	=	1	hectometer	=	10	dekameters	= 100 meters
0.01	kilometer	=	0.1	hectometer	=	1	dekameter	= 10 meters
0.001	kilometer	=	0.01	hectometer	=	0.1	dekameter	= 1 meter
1	meter	=	10	decimeters	=	100	centimeters	= 1 000 millimeters
0.1	meter	=	1	decimeter	=	10	centimeters	= 100 millimeters
0.01	meter	=	0.1	decimeter	=	1	centimeter	= 10 millimeters
0.001	meter	=	0.01	decimeter	=	0.1	centimeter	= 1 millimeters

Note: The Metric System is consistent. In the above table, liter or gram may be substituted for meter and the table is still true.

AREA IN THE METRIC SYSTEM

Measure	Symbol	Relationship
Square centimeter	cm^2	1 cm^2 = 100 mm^2
Square decimeter	dm^2	1 dm^2 = 100 cm^2
Square meter (1 m x 1 m)	m^2	1 m^2 = 100 dm^2
Are (10 m x 10 m)	a	1 a = 100 m^2
Hectare (100 m x 100 m)	ha	1 ha = 100 a = 10 000 m^2
Square kilometer	km^2	1 km^2 = 100 ha = 1 000 000 m^2

Note: 1 ha = 2.5 acres

VOLUME IN THE METRIC SYSTEM

Measure		Symbol	Relationship
Cubic centimeter		cm^3	1 cm^3 = 1 000 mm^3
Cubic decimeter		dm^3	1 dm^3 = 1 000 cm^3
Cubic meter		m^3	1 m^3 = 1 000 dm^3
Liquid	Milliliter	mL	1 cm^3 = 1 mL
Liquid	Liter	L	1 dm^3 = 1 L
Liquid	Kiloliter	kL	1 m^3 = 1 kL

metre = meter
litre = liter

METRIC REFERENCE TABLE

Root Word	Added Prefix	Prefix Means	Results	Written as a Measure	Written as a Unit	For Daily Use	Approximate Equivalent
	milli	1/1000	1 millimeter	0.001 m	1 mm	yes	0.039 inch
	centi	1/100	1 centimeter	0.01 m	1 cm	yes	0.39 inch
	deci	1/10	1 decimeter	0.1 m	1 dm	avoid	
(1) METER			1 meter	1 m	1 m	yes	39.37 inches
	deka	10	1 dekameter	10 m	1 dam	avoid	
	hecto	100	1 hectometer	100 m	1 hm	avoid	
	kilo	1000	1 kilometer	1 000 m	1 km	yes	0.62 miles
	milli	1/1000	1 milliliter	0.001 L	1 mL	yes = 1 cm^3	0.03 fluid ounce
	centi	1/100	1 centiliter	0.01 L	1 cL	avoid	
	deci	1/10	1 deciliter	0.1 L	1 dL	avoid	
(2) LITER			1 liter	1 L	1 L	yes = 1 dm^3	1.06 quarts
	deka	10	1 dekaliter	10 L	1 daL	avoid	
	hecto	100	1 hectoliter	100 L	1 hL	avoid	
	kilo	1000	1 kiloliter	1 000 L	1 kL	yes = 1 m^3	264 gallons
	milli	1/1000	1 milligram	0.001 g	1 mg	yes - science and medicine	
	centi	1/100	1 centigram	0.01 g	1 cg	avoid	
	deci	1/10	1 decigram	0.1 g	1 dg	avoid	
(3) GRAM			1 gram	1 g	1 g	yes	0.035 ounce
	deka	10	1 dekagram	10 g	1 dag	avoid	
	hecto	100	1 hectogram	100 g	1 hg	avoid	
	kilo	1000	1 kilogram	1 000 g	1 kg	yes	2.2 pounds

1 000 kilograms = 1 metric ton, about 1.1 short tons

All You Will Need to Know About Metric

(For Your Everyday Life)

10

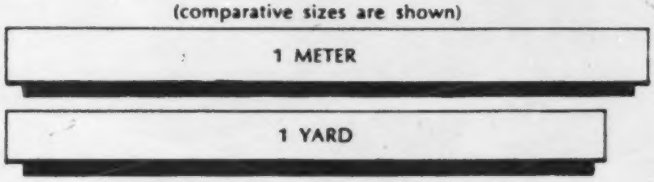
Metric is based on Decimal system

The metric system is simple to learn. For use in your everyday life you will need to know only ten units. You will also need to get used to a few new temperatures. Of course, there are other units which most persons will not need to learn. There are even some metric units with which you are already familiar: those for time and electricity are the same as you use now.

BASIC UNITS

METER: a little longer than a yard (about 1.1 yards)
LITER: a little larger than a quart (about 1.06 quarts)
GRAM: about the weight of a paper clip

(comparative sizes are shown)



25 DEGREES FAHRENHEIT

25 DEGREES CELSIUS

COMMON PREFIXES

(to be used with basic units)

Milli: one-thousandth (0.001)
Centi: one-hundredth (0.01)
Kilo: one-thousand times (1000)

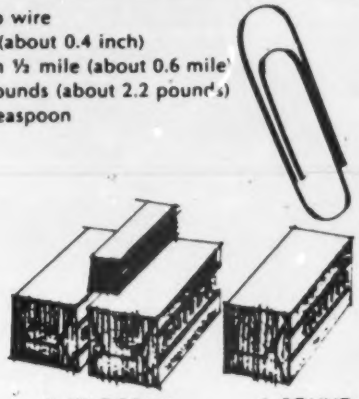
For example:
1000 millimeters = 1 meter
100 centimeters = 1 meter
1000 meters = 1 kilometer

OTHER COMMONLY USED UNITS

Millimeter:	0.001 meter	diameter of paper clip wire
Centimeter:	0.01 meter	width of a paper clip (about 0.4 inch)
Kilometer:	1000 meters	somewhat further than ½ mile (about 0.6 mile)
Kilogram:	1000 grams	a little more than 2 pounds (about 2.2 pounds)
Milliliter:	0.001 liter	five of them make a teaspoon

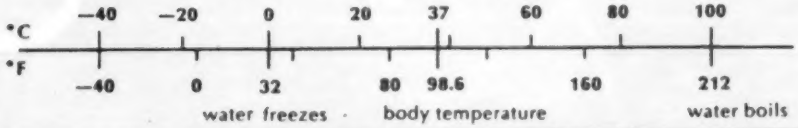
OTHER USEFUL UNITS

Hectare: about 2½ acres
Tonne: about one ton



TEMPERATURE

degrees Celsius are used



For more information, write to: Metric Information Office, National Bureau of Standards
Washington, D.C. 20234

or: Winston-Salem/Forsyth Metric Education Project
ESEA Title III, P.O. Box 2513, Winston-Salem, N.C. 27102

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